Four Light Total Appearance Imaging of Paintings

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Imaging artwork for documentation and reproduction has a long and rich history. The vast majority of such imaging reduces an illuminated three-dimensional object onto a two-dimensional plane, rendering a specific observing experience, defined by the photographer, conservator, or curator. It we can separate capture and rendering, the object can be re-rendered as criteria change. This can be accomplished by imaging the object's total appearance followed by computer-graphics rendering.

For paintings, a complete physical description includes spatially varying spectral reflectance factor, R_λ, surface macrostructure (depth or surface normal, *n*), and surface microstructure (bi-directional reflectance distribution function, BRDF). Measurements of R_λ, BRDF, and *n* can be accomplished with a single imaging system. However, if the object surface has appreciable impasto and is not matte, hundreds of images may be required to assure that both diffuse and specular reflections have been captured for every point on the object, which when combined with true spectral imaging, would require a complex research apparatus.

Beginning in 2006 a research program was initiated to develop a practical approach to measuring the total appearance of paintings, resulting in two lighting systems: one to measure n and R_λ and one to measure BRDF. The first system is the subject of this submission, referred to as "4LI": four light imaging.

Photometric stereo is a straightforward technique to measure *n*, requiring a minimum of three light directions using point sources. The images cannot have any specular highlights, achieved in this approach using cross-polarization. The imaging system was comprised of four polarized Broncolor strobes and a polarized Canon Mark II camera. Calibration included imaging a glossy black ball to define lighting geometry (RGB), setting cross polarization, and imaging a diffuse white board and color target (for spectral estimation using the Dual-RGB imaging system). The imaging system is shown in Figure 1. An advantage of this approach is that the object size is not limited. Eight images are collected for a given object: each light source and the dual-RGB (4 x 2 = 6). Automated software outputs diffuse color and surface normal floating-point images (PFM).

Software was written, "Artviewer," to render images interactively for specific lighting conditions, either a point source or museum lighting. The Ward model was used to define BRDF, set interactively or using an artist material database. Screenshots from the software are shown in Figures 2-4. "Isee" was also written to view the floating-point images, similar to HDR Shop.

Figure 1. Lighting and dual-RGB camera system undergoing testing in the Munsell Color Science Laboratory.

Figure 2. Screen shot of ArtViewer interactive software. Image is rendered using a point source (R=-1) from the normal.

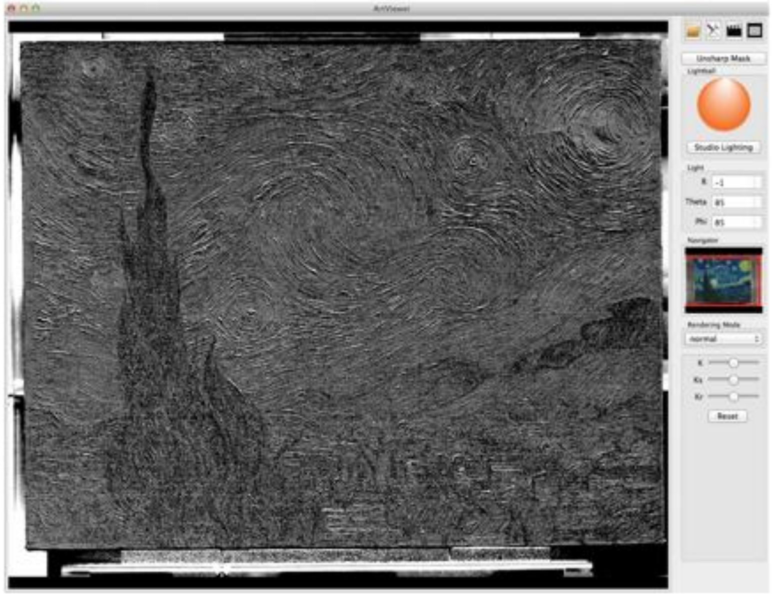

Figure 3. Surface normal map rendered using a point source from a grazing angle.

Figure 4. Rendering using studio lights at 45° from the left and right where the left side has three times more light intensity from a distance of two feet.

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